10 Years of Ocean Exploration at NOAA

In 2001, the National Oceanic and Atmospheric Administration (NOAA) created a program to explore Earth's largely unknown ocean for the purpose of discovery and the advancement of knowledge and to establish partnerships with commercial, academic, private, non-governmental, and government entities. This program, now part of NOAA's Office of Ocean Exploration and Research (OER), continues to advance NOAA and national goals to better understand the ocean through discovery, research, technology development, outreach and education. OER responds to emerging scientific issues leading to discoveries and new technologies that benefit society. The accomplishments highlighted here are examples of the breadth, diversity, reach, and importance of ocean exploration.

Exploring the Gulf of Mexico: Before and After the Oil Spill

Since 2001, OER has explored and characterized areas of key interest to NOAA and the nation, including the Gulf of Mexico. Beginning in 2004, OER combined funding and expertise across a multi-year partnership with the Bureau of Ocean Energy Management, Regulation and Enforcement, formerly the Minerals Management Service, to explore and characterize Gulf of Mexico deepwater habitats.

More Highlights:

- Provided a valuable foundation of data against which to measure potential change that may be connected to the MC252 Deepwater Horizon Oil Spill in April 2010, including damage assessment and long-term restoration efforts.

- Repurposed two expeditions in 2010 to obtain early and valuable data about the potential advance of oil and dispersants and to assess possible impacts on ecosystems.

- Hosted a national workshop to collect input from the scientific community on future exploration and research in the Gulf.

- Supported the engineering of an underwater mass spectrometer coupled with an autonomous underwater vehicle (AUV), used by the Coast Guard during spill response to detect hydrocarbons in the water column.

- Won the 2006 and 2007 Department of Interior's Cooperative Conservation and the 2006 National Oceanographic Partnership Program Excellence in Partnership Awards.

- Responded to educator and student interest in the impacts from the Gulf event by developing education materials and offering a three-week online educator professional development program to nearly 700 participants from 21 countries and 46 states.

- Supported development of the Gulf of Mexico Methane Hydrate Seafloor Observatory. It is estimated that up to 60% of the world's global carbon reserves are located within methane hydrates.

NOAA Ship Okeanos Explorer*: America's Ship for Ocean Exploration*

NOAA Ship *Okeanos Explorer,* the only federal ship dedicated to systematic ocean exploration, began operations in May 2010. After the U.S. Navy transferred the former surveillance vessel to NOAA in 2006, OER worked in partnership with NOAA's Office of Marine and Aviation Operations to design, refit, and ready the ship for operations. The ship has a state-of-the-art multibeam sonar system, a deep-water remotely operated vehicle (ROV) with high-definition video cameras, and advanced telepresence technology to connect shipboard personnel, images, and data from the ship and ROV to audiences ashore in real-time.

More Highlights:

- Collaborated with NOAA's Office of National Marine Sanctuaries (NMS) to map priority areas during the ship's sea trials in 2008 and 2009, including 35% or Cordell Bank NMS and 91% of its proposed expansion area; 7% of Gulf of the Farallones NMS and 31% of its proposed expansion area. In total, the ship mapped 2,226 square statute miles of central California's sanctuaries and proposed expansion areas.

- Collected bathymetric and habitat data with NOAA's National Ocean Service and National Marine Fisheries Service, as part of a west coast deep-coral project that began in 2010.

- Discovered an extraordinary 1,400-meter gas plume in the water column near the Mendocino Ridge off California using the ship's state-of-the-art mapping system.

- Supported NOAA's National Marine Fisheries Service in sampling plastics in the 'Pacific Ocean Garbage Patch' and collecting plankton during a record 5,000 nautical mile collection of plankton.

Opening International Doors: Indonesia-U.S. Ocean Expedition Advances Science and Diplomacy

In 2010, Indonesian and U.S. scientists explored Indonesian waters in a partnership that aligned with President Obama's vision to build relationships with Muslim-majority nations through sharing of science and technology. An international team led by scientists from the United States and Indonesia collaborated on a 38-day, two-ship expedition to explore the depths of Indonesian waters. The expedition was the maiden voyage of NOAA Ship *Okeanos Explorer* and featured live video from the seafloor to Indonesian and U.S. scientists in Exploration Command Centers ashore.

More Highlights:

- Mapped over 15,000 square miles of seafloor, including a seamount rising nearly 12,000 feet from the bottom and discovered a number of other seamounts.

- Conducted 27 ROV dives, the first deepwater dives in Indonesia's Sulawesi Sea.

- For the first time documented deepwater biodiversity in the Coral Triangle's Sulawesi Sea, imaging possibly 40 potential new coral species and 50 potential new species of other ocean animals.

- With The Exploratorium in San Francisco, conducted a series of live webcasts bringing mission explorers at sea in contact with teachers, students and the general public in the museum and via the Web.

- The expedition was part of a larger Indonesia-NOAA partnership in areas of exploration, fisheries, food security, climate observations and tsunami warnings.

Pioneering Telepresence Technology for Science and Ocean Literacy

Since 2003, OER has partnered with the Institute for Exploration (IFE) and Dr. Robert Ballard, whose vision of ocean exploration through telepresence technology has scientists ashore actively participating in expeditions at sea. Using telepresence technology and ROVs, NOAA Ship *Okeanos Explorer* and Dr. Ballard's Exploration Vessel *Nautilus* send high definition video from the seafloor live via satellite and high-speed Internet to scientists standing watch ashore in one of six Exploration Command Centers (ECCs). As scientists viewed live video from sea, they commented in an online chat room, identifying ocean animals or features, with their comments time-coded to the video. Telepresence technology will increasingly connect ocean expeditions with scientists, newsrooms, classrooms and living rooms, helping to advance science and raise ocean literacy through the excitement of real-time ocean discoveries.

More Highlights:

- In 2004, the National Geographic Channel gave audiences unprecedented access to a telepresense-enabled expedition by broadcasting a one-hour special from the NOAA Ship *Ronald H. Brown*, including live views of the RMS *Titanic* more than two miles deep on the ocean floor.

- The 2005 Lost City Expedition in the mid-Atlantic allowed for the first time, participation of an international science team, not at sea, but in shore-based ECCs at the University of Washington and the University of Rhode Island.

- In July 2010, *Nautilus* in the Mediterranean and NOAA Ship *Okeanos Explorer* in Indonesia conducted simultaneous telepresence-enabled expeditions. The University of Rhode Islands' Inner Space Center, the technical hub for telepresence-enabled expeditions, displayed live seafloor video from both ships as they made unique discoveries in two very different regions of the world ocean.

- ECCs ashore have been established at NOAA facilities in Seattle and Silver Spring Maryland, the University of New Hampshire, the University of Rhode Island, Mystic Aquarium in Connecticut, and in Jakarta, Indonesia.

Establishing America's Extended Continental Shelf

OER supports leadership, science, funding, and communications coordination for major portions of the U.S. Extended Continental Shelf Project, which has gathered and analyzed sonar and seismic data since 2003 to establish the full extent of the nation's continental shelf—beyond 200 nautical miles. International recognition of the extended continental shelf (ECS) helps establish stability for development, conservation and protection of these areas, which are likely rich in seafloor and sub-seafloor resources.

More Highlights:

- Partnered with NOAA's Office of Coast Survey to conduct the first U.S. Arctic ECS-related mapping expedition in 2003.

- The value of U.S. ECS resources has been estimated in the billions, if not trillions of dollars, and preliminary studies indicate the nation's ECS may be equal to an area about twice the size of California. OER coordinates much of NOAA's participation in the U.S. ECS Project—an interagency group chaired by the Department of State.

- Supported three international ECS Arctic expeditions involving the icebreakers U.S. Coast Guard Cutter *Healy* and the Canadian Coast Guard Ship *Louis St. Laurent*.

- Established a website at continentalshelf.gov to archive and present data from multi-year expeditions on behalf of thirteen U.S. and two Canadian government agency partners.

Explorations Leading to Research, Protection and Innovation

Baseline information discovered during OER-funded expeditions led to the designation of numerous protected ocean areas. Exciting discoveries during expeditions have also fueled research into emerging ocean concerns, such ocean acidification.

More Highlights:

- Information from early OER –funded expeditions was key to including of deep-sea corals in the 2006 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act and the establishment of NOAA's Deep Sea Coral Research and Technology Program in 2009.

- Eight expeditions off the U.S. Southeastern coast since 2001 provided a basis for the South Atlantic Fisheries Management Council to designate Habitat Areas of Particular Concern to protect deep corals and associated communities of life.

- Discoveries from a series of OER-funded expeditions played a major role in designating Marianas Trench Marine National Monument and expanding Monterey Bay National Marine Sanctuary to include Davidson Seamount.

- OER and other NOAA offices crafted the Guidelines for Research, Exploration and Salvage of RMS *Titanic.*

- In 2009 in the South Pacific, OER and partners discovered and captured high definition video of a violently erupting volcano 4,000 feet below the ocean's surface. It was the first recording of flowing boninite lava, seen before only associated with extinct land-based volcanoes a million years old or older. The discovery of this lava helps scientists understand basic Earth processes.

- Liquid droplets of carbon dioxide found rising from the seafloor in 2004 became a natural seafloor laboratory for scientists to study the effects of ocean acidification on marine life.

Establishing a Biodiversity Baseline

OER has long focused on the importance of ocean biodiversity and at-sea efforts to document the diversity and distribution of marine life. That focus continues and was key to the success of the 10-year Census of Marine Life (CoML) project.

More Highlights:

- Between 2002 and 2010, OER adapted more than 50 sponsored projects and expeditions as CoML projects, funding an estimated $24 million in ship time and science costs. OER and the National Science Foundation were the largest U.S. funders of CoML-associated at-sea expeditions.

- OER established and led a NOAA Biodiversity Team that contributed to interagency efforts to better understand marine biodiversity.

- Between 2002 and 2004, focusing on salmon, humpback whales, tuna and elephant seals, OER pioneered NOAA efforts to use animal-borne sensors to significantly increase the pace of ocean exploration.

Discovery and Protection of Maritime Cultural Resources

Since 2002, OER has been a substantial source of public funding in the discovery and protection of shipwrecks and other submerged cultural resources. Efforts include expanding the use of emerging technologies and introducing new methodologies to the field. Notably, OER's participation in two RMS *Titanic* expeditions set a precedent by adhering to the Guidelines for Research, Exploration and Salvage of the RMS *Titanic* that align with the United Nations model for the Protection of the Underwater Cultural Heritage. And as part of *AUVfest 2008*, OER worked with the Office of Naval Research, teaming with the Navy to apply advanced undersea technology to examine shipwrecks.

More Highlights:

- Supports foundational work on the continental shelf of North America for evidence of how the first humans migrated to the New World when facing the challenge of rising sea levels caused by climate change at the end of the Pleistocene ice age.

- Partnered with Dr. Robert Ballard and the Institute for Exploration to trace the development of western civilization through discovering shipwrecks in the Mediterranean and Black Seas.

- Partnered with the NOAA's Office of National Marine Sanctuaries and the U.S. Navy to raise the turret of the Civil War ironclad U.S.S. *Monitor*.

- Discovered the remains of *Trouvadore* in the Turks and Caicos Islands, the only slave ship known to be sunk after an international treaty to abolish slavery.

The Excitement of Discovery Engages Students, Teachers and the Public

Since 2001, NOAA's Ocean Exploration Program has consistently reached out to the public in new and innovative ways. OER engages educators and students in real-time ocean exploration to increase America's ocean literacy and student interest in the science, technology, engineering, and mathematics (STEM) disciplines and in ocean-related careers. Inquiry and standards-based education materials teach students about the importance of ocean exploration, the technological tools used to explore the deep and open ocean, and the valuable discoveries that have been made. Each year, hundreds of teachers participate in intensive onsite and online professional development workshops that extend to an estimated 100,000 students annually.

More Highlights:

- 40 million individuals have visited the program's award-winning website. In 2001, oceanexplorer.noaa.gov pioneered the chronicling of expeditions from sea with explorer logs and imagery.

- Over the course of 10 years, more than 450 lessons and supplementary background materials have been packaged to accompany OER expeditions, all aligning with the National Science Education Standards and, more recently, with the Ocean Literacy Essential Principles and Fundamental Concepts. In 2010 alone, more than 850,000 lessons were downloaded from the website.

- Three editions of the teachers guide, *Learning Ocean Science through Ocean Exploration* were produced and supported by educator workshops. Published *The NOAA* Ship Okeanos *Explo*rer *Education Materials Collection Volume 1: Why Do We Explore?* and developed a complementary educator workshop targeting with rationale for ocean exploration including climate change, energy, ocean health, and human health.

- OER led a NOAA-wide team in a five-year partnership with the Smithsonian Institution and others to envision, develop and open Sant Ocean Hall in National Museum of Natural History. Since this permanent exhibit opened in 2008, more than 12 million people have visited. This effort resulted in a team award of the Department of Commerce Gold Medal.

Did You Know?

- An OER-funded expedition in the Gulf of Mexico used Dr. Edie Widder's "Eye in the Sea," a system of cameras and lights designed to be undetectable by deep marine organisms. Immediately upon being deployed, the camera videotaped a previously unknown six-foot squid. Another mission deployed the system in complete darkness where an electronic lure flashed patterns of light. One pattern repeatedly elicited a

significant response from other organisms that flashed back, suggesting rudimentary communication with marine life.

- Light-tight, pressurized boxes, developed by OER partners allowed deep-sea animals to be brought to the surface without harming their eyes, leading to an unexpected discovery of ultraviolet vision in these animals. Such vision capability was not expected in the darkness of the deep-sea.

- Animal-borne sensors significantly increase the pace of ocean exploration, saving money and time while providing data describing areas of the ocean difficult for humans to access. For example, OER funded a mission in Greenland's Baffin Bay where sensors were placed on narwhals to gather critical ocean temperature data. Results indicated a warming trend since winter ocean temperatures were last measured there in the early 2000s – an important finding in our understanding of climate change.

- An OER research lab is funding a pilot program to tag elephant seals as "census takers" of tagged salmon at sea. The seals travel with salmon and collect data from salmon tags so that scientists can better understand why large numbers of salmon do not return from sea to spawn in streams.

- The OER Digital Atlas displays a ten-year, comprehensive map of expedition locations and provides a central point of public access to expedition specific data, information, and outreach materials for nearly 150 expeditions.

- The OER Video Data Management System provides wide discovery and access to expedition videos, images, and documents via NOAA Library's online search. More than 2,400 online documents were accessed by more than 382,000 unique visitors in 2010.

OER Technology and Methodology "Firsts"

2001

- First standard practice of providing the public image-rich daily content from at-sea expeditions

2002

- First expedition to include complementary human-occupied vehicle and autonomous underwater vehicle operations (Galapagos – R/V *Atlantis*, ALVIN, ABE)
- First deepwater remotely-operated vehicle deployed from an ice-breaker (Arctic 2002 – CCGC *Louis St. Laurent*)
- First Arctic expedition providing image-rich daily content to the public

2003

- First U.S. mapping expedition delineating the potential Arctic Extended Continental Shelf
- First expedition to broadcast live streaming video to shore (Black Sea-*Hercules*
- First deepwater ROV operated from a NOAA Ship (Deep Sea Medicines – NOAA Ship *Ronald H. Brown*, SONSUB Innovator)
- First expedition dedicated to using non-infrared optical techniques (Operation Deepscope-R/V *Seward Johnson*)

2004

- First prime-time live underwater TV broadcast (*Titanic* 2004-NOAA Ship *Ronald H. Brown*, Hercules ROV)
- First NOAA-Private Industry partnership in deepwater exploration (Deepwater Shipwreck Survey)
- First expedition cleared to conduct operations in both Russian and U.S. Arctic waters.

2005

- First expedition conducted with a shore-side Chief Scientist (Lost City 2005-NOAA Ship *Ronald H. Brown*, *Hercules* ROV)
- First icebreaker expedition dedicated to under-ice ROV operations (The Hidden Ocean 2005-USCGC *Healy*, Global Explorer ROV)

2006

- First expedition to conduct simultaneous human-occupied vehicle and autonomous underwater vehicle operations (Project PHAEDRA-R/V Aegaeo, SeaBED AUV, Thetis HOV)

2007

- First deepwater biodiversity expedition in the Coral Triangle region (Exploring the Inner Space of the Celebes Sea 2007-R/V *Hydrographer Presbitero*, Global Explorer ROV)
- First real-time use of an in situ mass spectrometer near Gulf of Mexico cold seeps

2008

- First opportunity for OER-sponsored Marine Archaelogists to embed with Navy teams to learn how Navy mine-hunting technology can be used to hunt for shipwrecks.

2010

- First time in more than 30-years a U.S. research vessel operated in Indonesian waters for the purpose of non-tsunami related science
- First NOAA-led expedition with *Okeanos Explorer* using telepresence (INDEX-SATAL)
- First non-U.S Exploration Command Center established in Jakarta, Indonesia